

Robots in education: New trends and challenges from the Japanese market

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Abstract. The paper introduces and compares the use of current robotics kits developed by different companies in Japan for education purposes. These kits are targeted to a large audience: from primary school students, to university students and also up to adult lifelong learning. We selected company and kits that are most successful in the Japanese market. Unfortunately, most information regarding the technical specifications, the practical usages, and the actual educational activities carried out with these kits are currently available in Japanese only. The main motivation behind this paper is to give non-Japanese speakers interested in educational robotics an overview of the use of educational kits in Japan. The paper is completed by a short description of a new pseudo-natural language we propose for effectively programming one of the presented robots, the educational humanoid Robovie-X.

Keywords: educational robot kits, humanoid robots, wheeled robots, education

Introduction

With the advance of technology, robotics have been successfully used and integrated into different sectors of our life. Industrial robot arms almost completely replaced the manual workload. Service robots, such as Roomba, serve as home helpers in the households, dusting the house automatically. Also in the field of entertainment, many robots have also been developed, the robot dog AIBO provides a successful example of this. Recently, several new robot aimed at “edutainment” have been proposed (Asada et al., 2000). Not only one is able to learn how to build a robot system, but also to have fun competing with others. Tournaments, such as Robocup (2012) and First Lego League (2012), have gained attention as events able to provide both education and entertainment at the same time.

Robotics offers a new way of teaching science to students (Nomura et al., 2008; Alimisis, 2009), especially when integrating it into standard class curricula. Robotics can also foster the interest for scientific and technical disciplines. In Japan particularly, there is a downtrend of interest in technology and science among the youngest (Nishimura, 2006). This could create a problem to a country where development of new technologies and manufacturing industries play such an important role. Robotics is expected to solicit the appreciation in technology and science and also enthusiasm in “making-artifacts” of the youngsters.

Introducing robotics in schools becomes popular nowadays and there is a larger and larger variety of commercial edutainment robots available in the market. For the sake of organizing the description, we broadly divided these robots in three groups. The first is reconfigurable robotics construction kits, like the Lego Mindstorms NXT (2012), which is widely used for education. In this first group, we will fit all robot construction kits which are not designed to create just one or two robot platforms, but that allows the student to create any shape and/or kinematic chain for his/her robot. Thus, the students can practice also with

mechanical design and construction and not only with electronic/mechanical assembly and software programming. We will not discuss these types of kits in this paper, because there are no major Japanese products in this group. The second group is wheeled robots. In this second group, we fit all robots which come already assembled in the shape of a car or even in kit if the possibility of the assembly is limited to one or two shapes of car. Finally, the last group is humanoid robots, which is still the less common type due to their cost and availability. Usually, humanoid robots come as construction kits, but some examples of already assembled humanoids exist.

In this paper, we discuss the products of three Japanese companies, namely Vstone (2012), ZMP (2012), and Elekit (2012). We selected these companies because they develop a range of both wheeled and humanoid robots, they are successful in the Japanese market, and they provide documentation and activity sheets on the educational experience proposed with the robots. Vstone, which is well-known worldwide because of its VisiON robot series which won five times the Robocup World Championship, develops several low cost educational robot kits aimed at students as early as primary school. ZMP provides a series of educational robots called e-nuvo, ranging from a basic kit to learn motor control, up to a full-sized car, mainly aimed at university students. Elekit developed several low cost wheeled robot kits and also a simple humanoid. This paper will discuss wheeled robots and humanoids separately.

Wheeled Robots

Wheeled robots refer to a car like robot with wheels; they often provide only 2 controls, left and right. Their main application is for line tracing race as an introduction of control systems. Some products offer the study of a control system of balancing an inverted pendulum. These robots are provided as kits, so the students are able to gain experience in building robots, including tightening screws, fitting gears, and also soldering.

Vstone's Beauto Series

This section will discuss three of the current models of Vstone's low cost (<30-90 €) wheeled robots, which are *Beauto Racer*, *Beauto Chaser*, and *Beauto Balancer*, their summary is shown in Table 1 (Vstone, 2012). Beauto series (as shown in Figure 1) offers the learning of programming from basic to using C programming on microcontrollers (Beauto Chaser, 2009).

Beauto Racer and *Beauto Chaser* share similar hardware specifications, with the main difference on the CPU. *Beauto Chaser* and *Beauto Balancer* can be also programmed in C language using HEW (a software development environment for microcontrollers produced by Renesas) while *Beauto Racer* is only programmable using the bundled software, *Beauto Builder R* (Figure 2). The blocks used for the flowchart are 10 for beginners and 4 extra for advanced users. These blocks allow the user to stop, make the robot turn or go straight, timing the instructions, turning on the LEDs, creating conditional and loop commands. The speed of the motor can also be set. Advanced users may use the memory map allocation to set variables such as the motor output.

The feature of *Beauto Chaser* is the ability to learn how to program a microcontroller. It is also possible to add an extra board, VS-WRC004, on top of VS-WRC003, so that it is able to control up to 4 different motors. The main application of the robot is obstacle avoidance utilizing its infrared distance sensor. Further use also includes following the light, and also following a path line, which is possible by facing the sensor downwards. By using C

programming, the user can also program the buzzer to play different music notes. With an additional extra kit, the user will be able to program the robot to be a remote controlled toy car. Using creativity, there are many different possible applications of the robot obtained just by adding extra kits.

Table 1. Wheeled educational robot series developed by Vstone

Categories	Beauto Racer	Beauto Chaser	Beauto Balancer
Aimed users	primary – junior high	junior high – university	senior high – university
Size (mm)	81 × 77 × 23	175 × 125 × 55	110 × 45 × 210
Weight	81g (battery on)	194g (battery off)	175g (battery on)
Motor	2 DC motors	2 DC motors	1 DC motor
Sensors	2 infrared sensors	1 infrared distance sensor	gyro board rotary encoder
CPU	VS-LT001	VS-WRC003	
	control 2 DC motors	control 2 DC motors	
Software	Beauto Builder R	Beauto Builder NEO HEW by Renesas	Balancer programmer HEW by Renesas
Battery	1 AA battery	4 AA batteries	

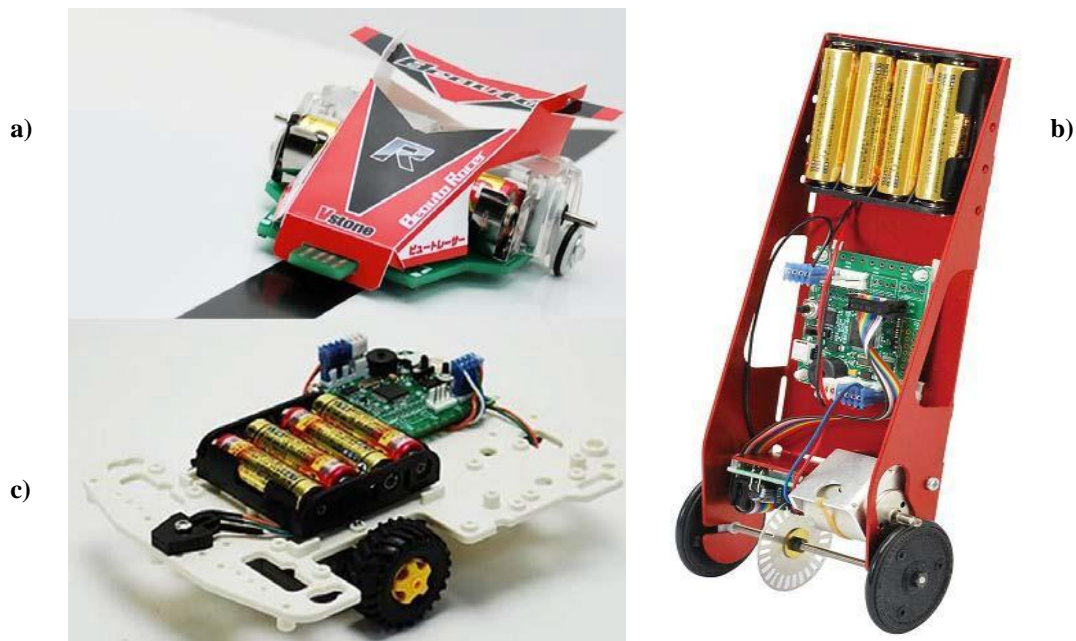


Figure 1. a) Beauto Racer, b) Beauto Balancer, c) Beauto Chaser

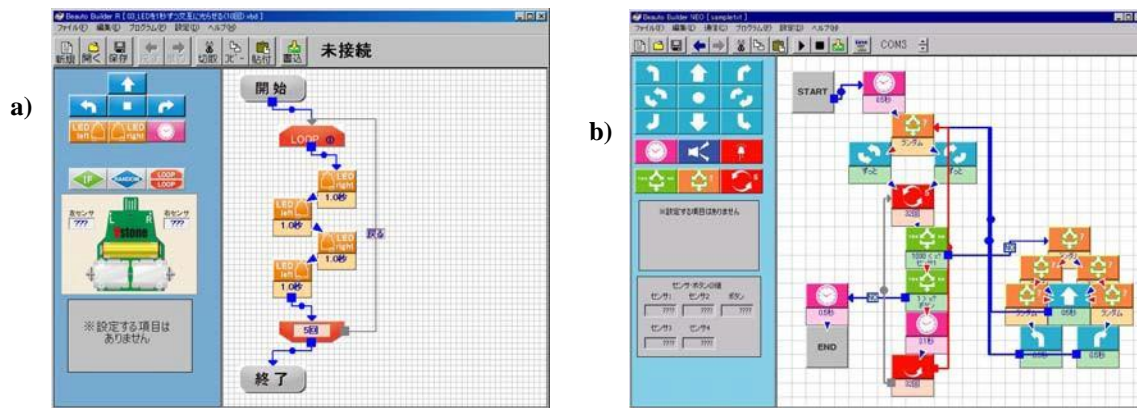


Figure 2. Vstone bundled software: a) Beauto Builder R, b) Beauto Builder NEO

The bundled software (*Beauto Builder NEO*) (Beauto Chaser, 2009) shares similar block flowchart interface as *Beauto Builder R*. Additionally, it is also possible to command the robot to move backwards, turn around, move slightly diagonal forward or backward, or turning on the buzzer. If the robot is connected to the computer, it is also possible to view the sensor's value in real time.

Beauto Balancer enables students to learn about how inverse pendulum works and control system for self-balancing. The famous product of a similar concept is Segway (www.segway.com). A single DC motor is used to make it go forward or backwards and to balance itself according to the info gained from the sensor. The assembly is simple, as it does not have many parts and can be done in less than one hour. Once the robot is built, the user can directly test the balancing program already inserted into the board. If the robot is well balanced, it is even safe to put things on top of it (Beauto Balancer, 2009). Similar as *Beauto Chaser*, it is possible to add extra sensors for more capability, or additional boards for controlling more motors and wireless controller kit. By using a simple Windows GUI provided by Vstone, the user is able to change the integral and differential gain for gyro and encoder without the need to use code programming. The user is able to change between 2 modes, still mode or moving mode. The speed and acceleration can also be set from the program. It is easy to use for beginners, but also offers flexibility for advanced users by providing the ability to program the microcontroller. The unique and simple design of the low cost *Beauto Balancer* allows the use of it as a learning kit to study control systems in Mechatronics course. By using the kit, it is hoped that the students are able to grasp the concept of why things can be controlled using classical control theory and modern control theory.

e-nuvo WHEEL

ZMP offers wheeled robots and the basic kit starts at ¥140,900 (€ 1,258). This robot is upgradable with option packs, which leads to the possibility of higher steps in learning. With the simple design of the robot, the students can understand modern control systems better and also learns how to utilize gyro sensor and encoder. It can be simulated through MATLAB, so the user can gain experience in simulating robots on computers. Aimed mainly at university students, they can learn programming, motor control such as PWM and H-bridge, line tracing experiment, classical control system (PID), modern control system, and model based design. It is controllable through wireless network (optional pack) and also through MATLAB, making it convenient to use as a tool to learn various algorithms, such as avoiding obstacles and behavior planning.

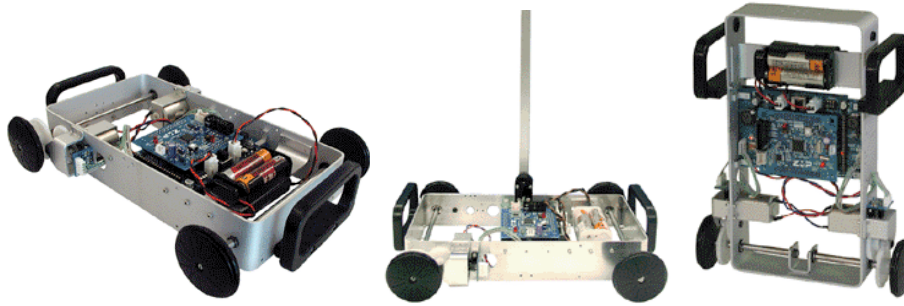


Figure 3. Variations of e-nuvo WHEEL, from left to right, line tracing, inverted pendulum, and two wheels balancing



Figure 4. Elekit MR-005, KIROBO MR-9132, and the software IconWorks

As mentioned above and shown in Figure 3, the robot basic kit comes as a 4-wheeled robot, where the students learn basic microcontroller programming (on H8 microprocessor) and basic motor control system. When the optional packs are applied, the robot can imitate an inverted pendulum and also be a 2-wheeled robot, where the students learn balancing control system.

Elekit MR Series

Elekit develops two types of wheeled robots (see Figure 4). The lower cost one, MR-005, which is only equipped with 1 light sensor which requires soldering to assemble, at a cost of ¥2,940 (€ 26). The KIROBO MR-9132, which does not require soldering and takes less time to assemble, is equipped with 2 light sensors and 2 touch sensors and can be purchased at ¥5,775 (€ 51). Both are aimed at users older than 12 and programmable using the bundled software, IconWorks. Like Vstone's one, also Elekit's software uses mainly an icon-based interface to enable beginner users to program the robot with a flowchart-like form. The functionality is also similar: it allows the user to make the robot move, read sensor info, incorporating timings, and basic programming instructions.

Humanoid Robots

Two-legged humanoid robots are particularly popular in Robocup soccer (Kitano & Asada, 1998) and Robo-one (2012) competitions. Combining soccer and humanoid robots create an interesting combination that grasps students' attention and creates motivation, and thus represents both a great potential as an education tool and a way to stimulate development of new technologies by younger people. Unfortunately, programming a humanoid it is not a trivial task (so far) and requires a considerable background in programming, physics, and mathematics. Several tools have been proposed to lower the complexity of humanoid robot

programming (Nomura, 2008; DallaLibera, 2008; Kuroki, 2003; Pierris, 2009). The companies we are discussing in this paper created their own editor for robot motion with pros and cons we will discuss in the next paragraphs. In the end, we will discuss the didactical motivation for using humanoid robots and present our contribution to a new language to program robot's motions in pseudo-natural language to mask the complexity of humanoid motion programming to non-advanced users.

e-nuvo WALK

The humanoid robot offered by ZMP at ¥560,000 (€ 5,000) has 12 degrees of freedom and is equipped with Intelligent Servo Module (Figure 5). This robot provides further study of control systems from respect with *e-nuvo WHEEL*. The board has 2 analogic ports and 4 digital ports, allowing extension of the robot's ability by adding USB cameras or sensors such as pose or range finder sensors. The control system of the robot is applied through CAN (Controller Area Network), which is a system widely used in commercial cars. This allows the usage of the robot as a tool of product development in companies.

e-nuvo WALK utilizes distributed control system, by dividing the control system to a higher rank (on PC), and joint control system (on the robot). Both development of real and virtual robot is performed through Microsoft Robotics Developer Studio (2012), which is an efficient robot control system development environment. Developing the motions of the robot is made easier by having a 3D image of the robot so that the user can check footsteps of the robot. So, even if there is no hardware, virtual development is made possible since it is equipped with a 3D simulator. Since this software uses .NET Framework, various programming language, such as Visual C# and Visual C++, can be used. Visual Programming Language is also available, making it easy to program, for example, using XBOX 360's controller to control the real or virtual robot.

Gogic Player

Elekit offers a simple humanoid robot kit that is equipped with 5 servo motors, and allows a variety of motion programming and exposure to a control system. Due to the small number of degrees of freedom, it is relatively simple and requires no complex setting. The kit can be assembled in 2-3 hours. The bundled software, Gogic Works, comes with two different skins, for beginner and advance users. The robot is controllable with a general TV remote control; mobile phones that have this function can also be used to control the robot.

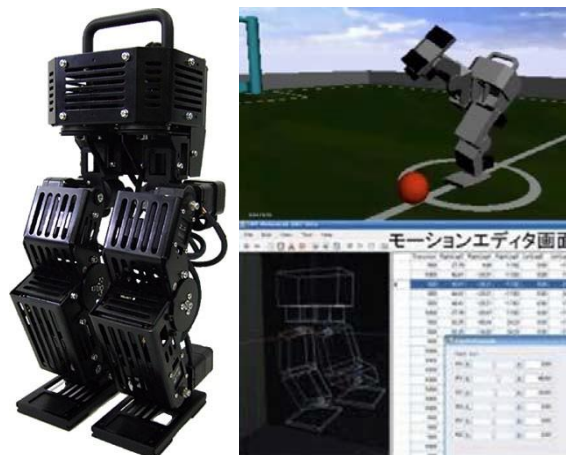


Figure 5. *e-nuvo WALK* (left), simulation environment, and motion editor (right)



Figure 6. Gogic Player and its transformation (left) and the bundled software (right)

With the equipped distance sensor, the robot can be programmed to move independently, with functions such as searching for people. The possibility to create complex motion is limited by the simple programming environment, which does not offer many facilities to the programmer. With extra optional packs, the robot can be made into a transformer robot (see Figure 6), allowing the robot to change from a humanoid form to a car form and vice versa.

Robovie

Robovie-i: This type provides a low cost 2-legged robot (shown in Figure 7). The “i” in its name corresponds to “introduction”, as expected to be easily handled by beginners, even primary school students. The robot can be easily assembled using just a screwdriver. The robot has 3 degrees of freedom, 2 for the legs and 1 for the waist. The CPU used is VS-RC003, which can be used to control 30 channel servomotors. Decoration stickers such as eyes and mouth are also included in the kit to add fun for the users. It is compatible with additional kits such as a wireless controller and a speaker for making it talk and it can also connect with sensor kits such as a gyro sensor. The software used to operate this kit is *RobovieMaker* (shown in Figure 7). The kit is interesting for beginners in robotics, not only because it can be easily assembled, but because it is easy to make motions such as walking due to its innate stability. After the student finishes studying *Robovie-i*, the kit is also upgradeable to RB2000, a real 2-legged robot with 13 degrees of freedom. Basic robotics knowledge, such as walking motion and the concept of center of mass, learned using *Robovie-i* could be applied on RB2000 making it easier to learn to control a more complex robot. By incorporating simple sensors, the robot can be programmed to react to sensory information. Some applications include sumo competition, or dancing synchronously with music.

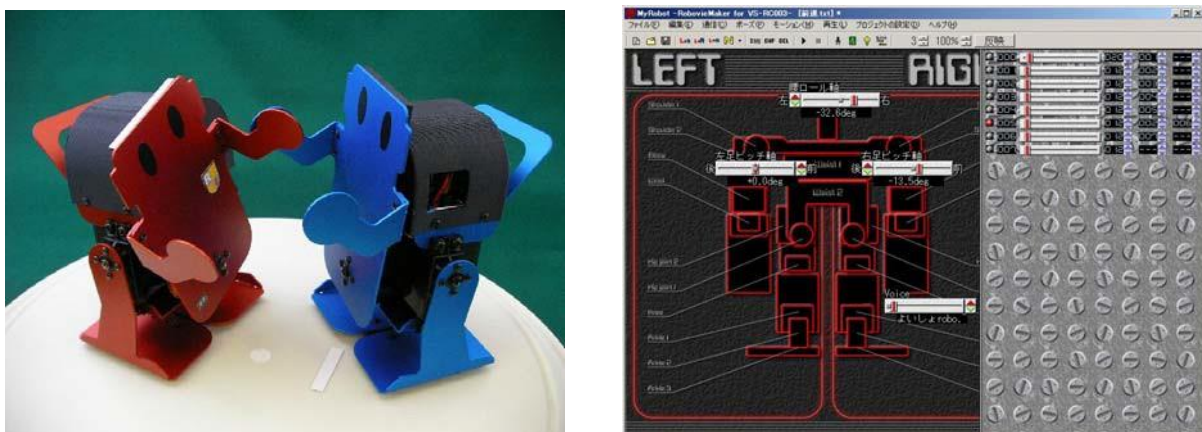


Figure 7. Robovie-i (left), and the bundled software RobovieMaker (right)

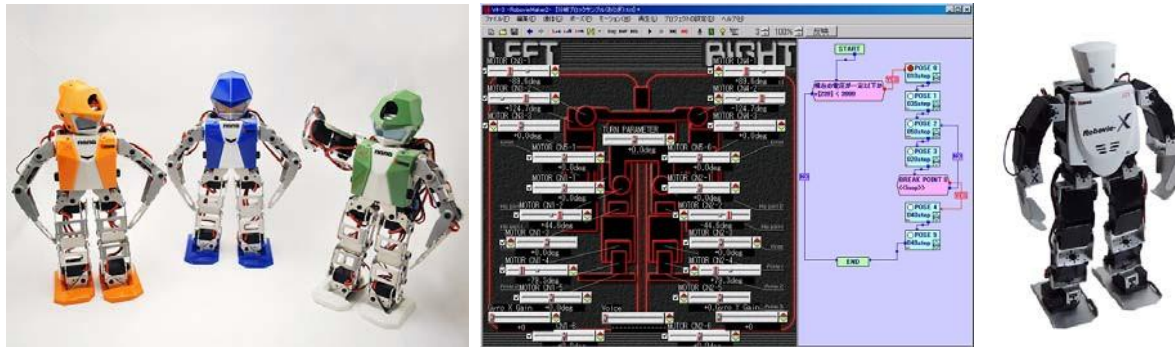


Figure 8. Robovie-nano (left), the bundled software RobovieMaker2 (middle), Robovie-X (right)

RobovieMaker: The robot motions can be developed with the bundled software *RobovieMaker* by connecting the robot via USB. The motion is created by moving each joint by a slider interface to create poses, and these several poses are then put into a sequence, like an animation, to form a motion. Since only moving sliders are needed, no programming skill is required. The users may use the included default motion as a base to create their own motion.

Robovie-nano: This model is a low cost entry level robot kit. It is only 23 cm high and weighs 575g (see Figure 8 left). The CPU is VS-RC003HV and it has 15 degrees of freedom. Its legs exploit parallel links, allowing more stable motions. Even in the basic version, it is equipped with speakers. Additional available sensor kits include a gyro sensor and extra motors to extend the degrees of freedom of the robot.

RobovieMaker2: This software, bundled with *Robovie-nano*, is an improvement of *RobovieMaker*: it enables the user to incorporate the integrated gyro sensor info and LED into the motion. When you have defined a pose on the left side of the interface (see Figure 8 middle), you can add it into the Motion Area on the right side where poses are connected into a sequence that forms the program (Figure 8 right). In the motion sequence the programmer defines also the duration of the transition from one pose to the following one, fixing the global motion speed. The sequence may also include conditional controls commands, cycles and calculations on global variables. The input from a game controller, which can be used to control the robot, or additional sensors (like gyroscopes and accelerometers) to improve stability can also be incorporated into the flowchart program.

Robovie-X: The *Robovie-X* (see Figure 8 right) is the biggest model and comes with seventeen degrees of freedom, with dimensions 343×180×71mm (H×W×D) and weight 1.3kg. It features VS-S092J servos which have 9.2kg/cm of torque. The VS-RC003HV onboard controller features a built-in audio system and an IXXBUS connector which allows optional expansion boards to be incorporated into the robot to expand its functionality. This robot has high motion performances, capable of fast walking, dancing, flip, side-flip, standing-up, fighting, playing soccer, etc.

Educational humanoid: a new challenge

Comparing with simple, wheel equipped vehicles, humanoid robots offer new questions on how using them in an effective learning way. One of the most relevant challenges is related to the relatively low level of abstraction their programming environments provide. This is essentially due to the complexity of the robotic structure: the relatively big number of degrees of freedom does not permit to maintain easily accessible the level of programming you can usually find in simpler types of robots like robot cars. We will show this using the

Robovie-X humanoid and then proposing a higher level of abstraction through a natural language programming interface.

This robot may be programmed using the *RomovieMaker2* GUI presented above. The programming environment compiles the program sequence into a textual, low-level command file, which is downloaded onto the controlling card and there executed. Despite the graphical interface provided, programming the robot in this way is a rather complex task and it requires a significant degree of expertise in order to produce stable poses and reasonable behaviors for the humanoid. This difficulty suggested us to experiment a higher level approach based on a pseudo-natural command language whose keywords should have been unambiguous, self-explaining and related to the robot capabilities. Moreover, the language should have given the possibility to easily define high-level actions.

The first step was to assign names, defined as language keywords, to all the joints of the robot. The 17 joints have been divided into one single joint on the head and 8 couples of joints for each side. So we identified these names: *head, shoulder, arm, elbow, hip, thigh, knee, calf, ankle* and the sides *left* and *right*. Then we identified some basic actions like: *move* (equivalent to *turn*), *increase, decrease, set*. In general the motion specifies a direction, described by: *inside, inward, outside, outward, front, forward, back, backward, right, rightward, left, leftward*.

The general structure of a motion command is:

<action> <side> <limb> <prep> <number> *degree* <direction>

<prep> is one of the two preposition *at* and *of* which respectively indicate the absolute and relative amount of degree specifying the angular position of the servomotor. <side> is not present in the case of the head joint. For the 2 LEDs, the command structure is slightly different:

<action> <side> *luminosity* <prep> <number> %

Every type of sensors is described by a specific keyword: *gyrox, gyroy, shootanalog, pitchmove, rollstep, rollstep, legpace, turnctr*. For controlling these elements in terms of gain or control, the command structure is:

<action> <side> <sensor> *gain/control* <prep> <number>

The previous commands can also be extended including the playing of a sound:

... *playing* <file pathname>

To set the transition time of a pose, it is sufficient to add the following suffix:

... *in* <integer value> *millisecond*

More than one action can be concurrently executed, separating two subsequent actions by a comma (,) or by the keyword *and*, and concluding the set of actions with a dot (.). Nestable cycles are easily programmed using this structure:

repeat <integer value> *times* ... <actions> ... *end*

As mentioned before, we tried also to include some higher level actions, that are sequences of predefined poses realizing useful behaviors. The complexity of the action, in terms of the number of parameters, depends on its type.

walk <integer value> *steps ahead/back/rightward/leftward*

dance

bow

We developed a compiler able to translate these natural language commands into the program text file expected by the robot controlling card. As you can see, this language makes it possible to break down the complexity in the effective programming of a humanoid for educational purposes and opens also the possibility of implementing vocal commands.

Summary and Conclusions

A selection of current available educational robot kits by 3 different companies has been presented. The robot kits introduced in this paper are summarized in Table 2. Wheeled robots are mainly targeted towards younger students while humanoid robots are more suitable for mature users. Since the robots come in kits, the users learn how to build a robot and how to use various sensors to increase the robot's intelligence. The provided software of the robot kits are mostly aimed at beginners who can begin learning programming by arranging instruction blocks in sequential, conditional, or repetition structures, in a flowchart like a graph. Some kits with an included microcontroller allow advanced users to learn microcontroller programming and also learn C language. e-nuvo series uses commercial programs such as MATLAB, enabling users to learn one of widely used engineering tools, and Microsoft Robotics Studio, which opens up the possibility of simulation of virtual robot. With additional kits or upgrades, there are more possibilities to use robots. In the end, we highlighted how the use of humanoid robots need more advanced programming languages and programming environments: we proposed a simple pseudo-natural language for humanoid robot programming. The development of these kits and their uses in different types of competitions, are expected to raise the youth's interest in science and technology.

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